DEVICES AND PROCESSING IN A MOBILE RADIO COMMUNICATION NETWORK HAVING CALIBRATION TERMINALS

FIELD OF THE INVENTION

The invention pertains to the field of mobile communications. The invention addresses the problem of increasing the accuracy of determination of the location of a mobile unit of a communication system, for example, a CDMA system.

BACKGROUND OF THE INVENTION

In some jurisdictions, regulatory requirements are in force, or planned, that require mobile communication network operators to report the location of a mobile terminal of the network when the mobile makes a call to an emergency service bureau. In the United States, for example, the reported location is required to be accurate to 125 meters in 67% of the cases. Such systems therefore require a reliable manner of accurately determining the location of a mobile. Various other services that require knowledge of the location of a mobile are being provided or are in development.

One way to determine the location of a mobile in an ideal synchronous mobile radio communication system (i.e. one in which all base stations maintain the same or known transmission frequencies, and in which there is a known, stable timing relation between the beginning of transmissions, or of timing markers, transmitted from each base station) is through measurement of the time difference of arrival (TDOA) of radio signals from base stations of the network at the mobile. By measuring the difference in arrival times of radio signals from two base stations having a known timing relationship, the location of the mobile may be determined to lie somewhere along a hyperbolic surface (hyperboloid) between the base stations. If the TDOAs three base or more station pairs are known, the intersection of the hyperboloids defined by the TDOA measurement for each base station pair indicates the geographic position of the mobile. Alternatively, mobile location may be determined through measurement by three or more base stations of the TDOA of signals from a mobile.

The use of TDOA measurements for location determination is dependent upon precise measurements and precise synchronization of network elements. Time of arrival differences must be measured to sufficient resolution to locate a mobile with the desired position accuracy. A TDOA measurement or synchronization error of one microsecond will yield a positional error of approximately 300 meters. Present CDMA mobile communication systems, for example, systems based on the TIA standard IS-95, are designed to provide synchronization of signal timing to within a microsecond. However, this timing uncertainty and the resulting positional error still limits the practical applications of mobile TDOA location services.

SUMMARY OF THE INVENTION

It is an object of the invention to facilitate greater accuracy in mobile location determination.

In general terms, the invention accomplishes this object by measuring the TDOAs of signals from base station pairs at a known location and comparing these measured TDOAs to expected TDOAs to generate correction factors that may be applied to TDOA measurements made by mobiles to reduce errors in mobile location determination and to reduce the need for base station synchronization.

A variety of system processes, system elements and element functionalities are described below in accordance with various embodiments of the invention.

DESCRIPTION OF THE DRAWINGS

The invention will be understood through reference to the following detailed description and the accompanying Figures, in which:

FIG. **1** shows a conventional CDMA communication system;

FIG. **2** shows the manner in which TDOA measurements are conventionally used for location determination;

FIG. **3** shows a CDMA system in accordance with the invention;

FIG. **4** shows a first system process in accordance with the invention;

FIG. **5** shows a second system process in accordance with the invention;

FIG. **6** shows a third system process in accordance with the invention;

FIG. **7** shows a calibration terminal in accordance with the invention;

FIG. **8** shows a base station in accordance with an embodiment of the invention;

FIG. **9** shows a process in a calibration terminal in a first network configuration in accordance with the invention;

FIG. **10** shows a process in a location server in a third network configuration in accordance with the invention;

FIG. **11** shows a process in a base station in accordance with a fifth network configuration in accordance with the invention; and

FIG. **12** shows an alternative process in a base station in accordance with a fifth network configuration in accordance with the invention.

DETAILED DESCRIPTION OF THE INVENTION AND PREFERRED EMBODIMENTS

The invention pertains to devices and processes in a mobile radio communications network comprised of elements that are frequency synchronized, i.e. that oscillate at essentially the same frequency. The invention is embodied in a variety of system processes for generating and using data produced by calibration terminals. Moreover, a variety of functionalities for mobiles, calibration terminals, location servers and base stations in accordance with the invention are contemplated. The particular functionalities provided to mobiles, calibration terminals, location servers and base stations to achieve system processes and subprocesses in accordance with the invention will be determined in part by the performance specifications of the network in which they are implemented. To facilitate a complete understanding of the invention and the many alternatives that may be considered in formulating an implementation, the remainder of the disclosure is presented in three parts. The first part provides an overview of TDOA-based location determinations and the manners in which these determinations are enhanced in accordance with the invention. In the second part, system processes implemented in a network as a whole in accordance with the invention are discussed. The third part provides a discussion of various alternative embodiments of calibration terminals, and describes various corresponding functionalities and interactions of calibration terminals, mobiles, base stations and location servers for carrying out the system processes discussed in the second part.